Recent Results on Top and Electroweak Physics from CDF

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XXXVIIIth Rencontres de Moriond

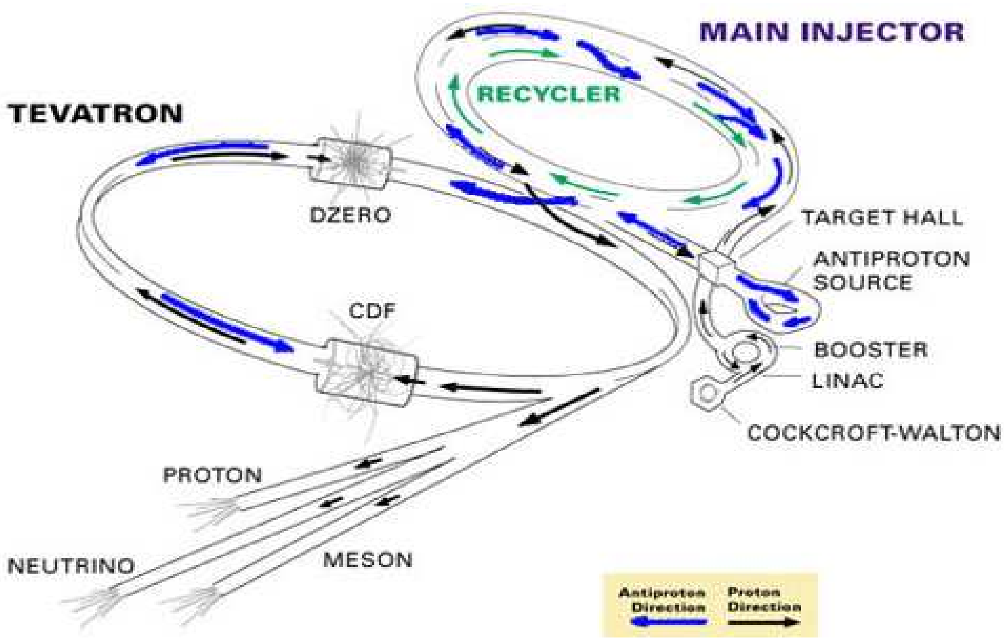
ELECTROWEAK INTERACTIONS AND UNIFIED THEORIES

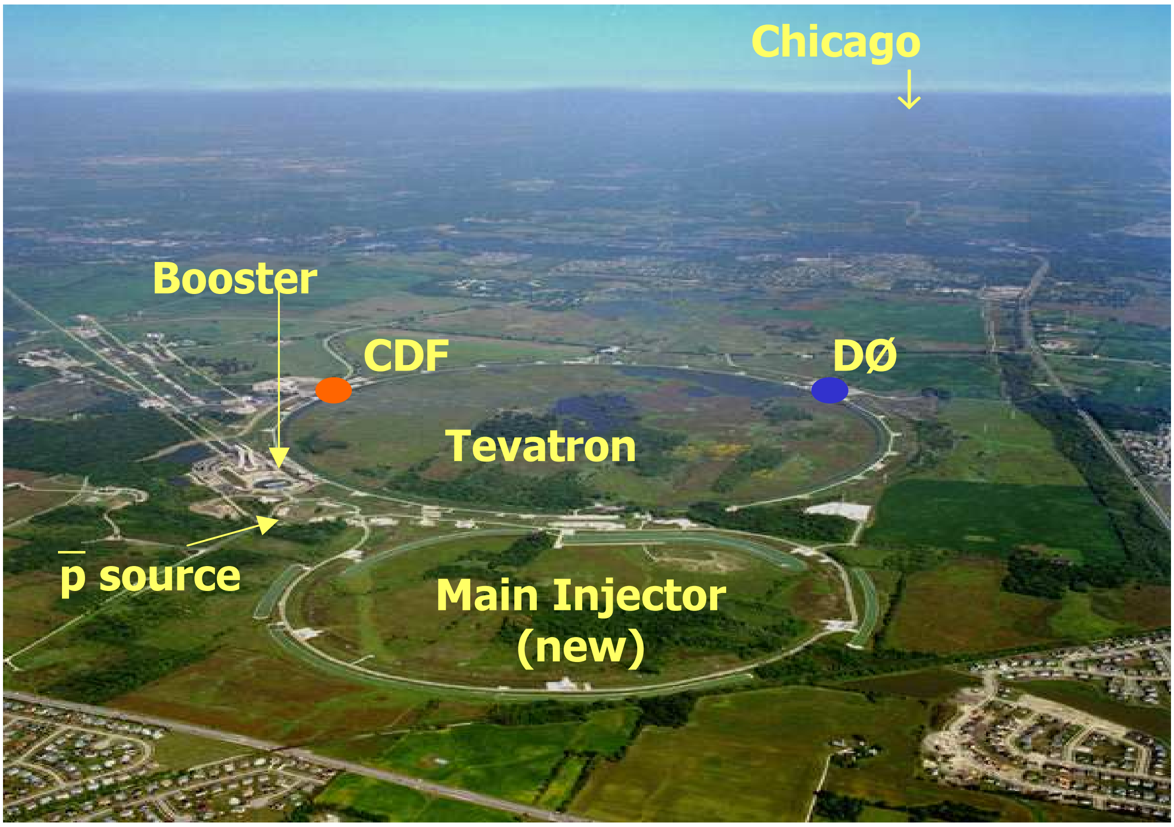
March 21, 2003

- Performance of the Tevatron/CDF
- Electroweak Physics
  - W/Z production cross sections and Ratios
  - Forward-Backward Asymmetry
  - WW production
- Top Physics
  - Top production cross sections
  - Top mass
- Summary

Fermilab Tevatron

Operated with proton bunches on antiproton bunches at CM energy of 1.96TeV



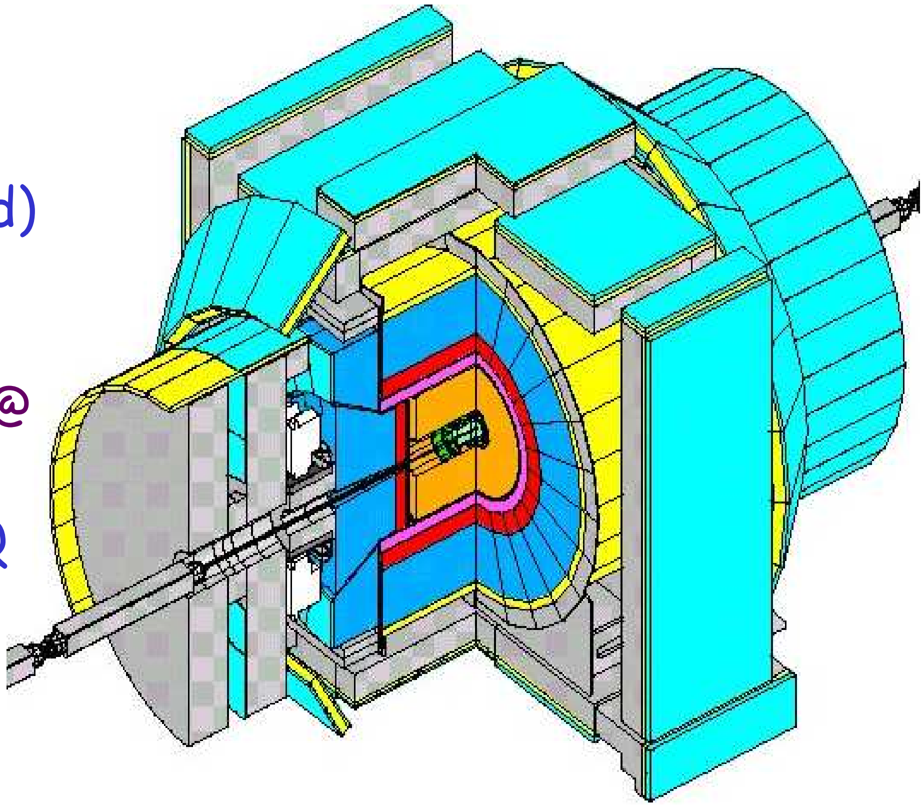


Run 2 CDF Detector

Upgraded Components

- Tracking
  - Silicon
    - 707K channels
    - Full Coverage of luminous region
    - Radial coverage from 1.35-28cm
  - Central Outer Tracker
    - 30k sense wires, 44-132 cm
    - 96 dE/dx samples/track
- Time of Flight
- Expanded Muon Coverage
- Endplug Calorimeter
- Trigger (pipelined)
  - Drift Chamber Tracks @ L1
  - Silicon Tracks @ L2
- Fully Digital DAQ (132 ns)

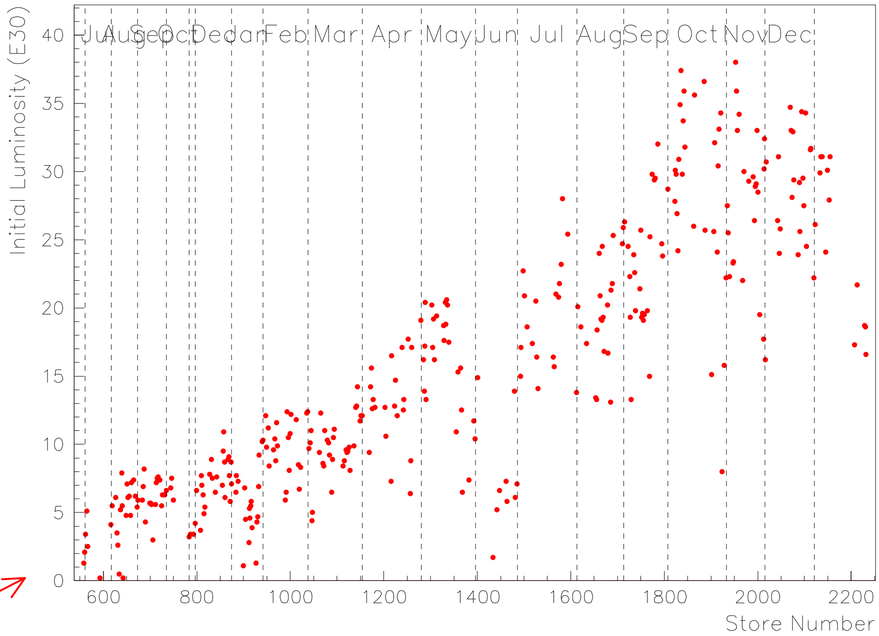
Collider Detector at Fermilab II



Current Tevatron status

Run 2a goal is
5-8 X 10^{31}

Initial Luminosity (10^{30} cm^{-2} s^{-1})

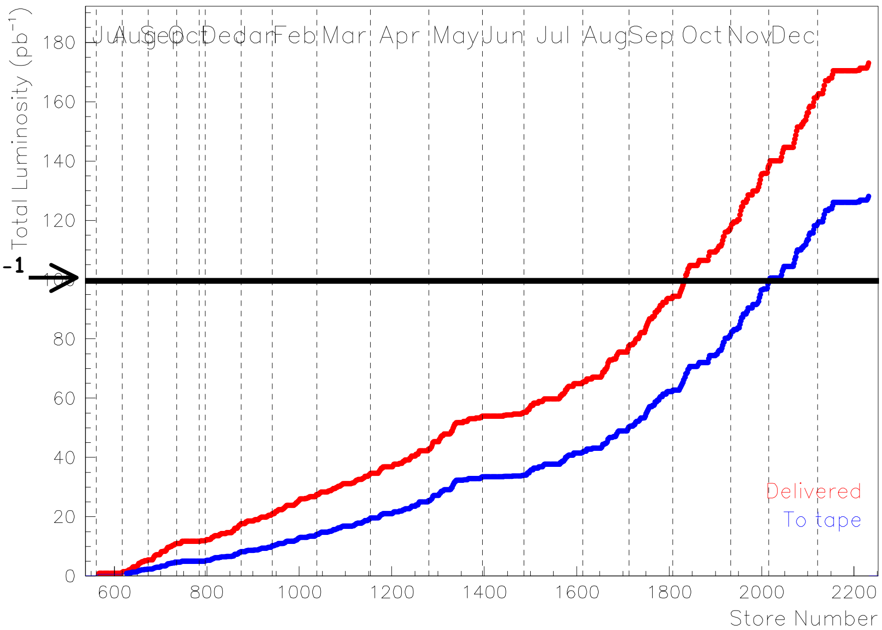


July 2001

~ 130 pb^{-1} on tape

~ 5-7 pb^{-1}/wk @ > 90% efficiency

Integrated Luminosity pb^{-1}



100 pb^{-1}

Run 2a goals:

16 pb^{-1}/wk

250 pb^{-1} by summer'03

2 fb^{-1} for Run 2a

Overview of EWK

First priority is to reestablish baseline measurements:

- $W \rightarrow \ell\nu$, $Z \rightarrow \ell\ell$ Cross Sections
- Ratio of W/Z Cross Sections
- Forward/Backward Asymmetry

Goal is to improve our understanding of the Standard Model EWK parameters.

W Charge Asymmetry

- Constraints on PDFs

W Mass Measurement

- Dominated by Systematics

Diboson Production

- WW, WZ, $W\gamma$
- Triboson Couplings
  - Anomalous couplings may indicate New Physics

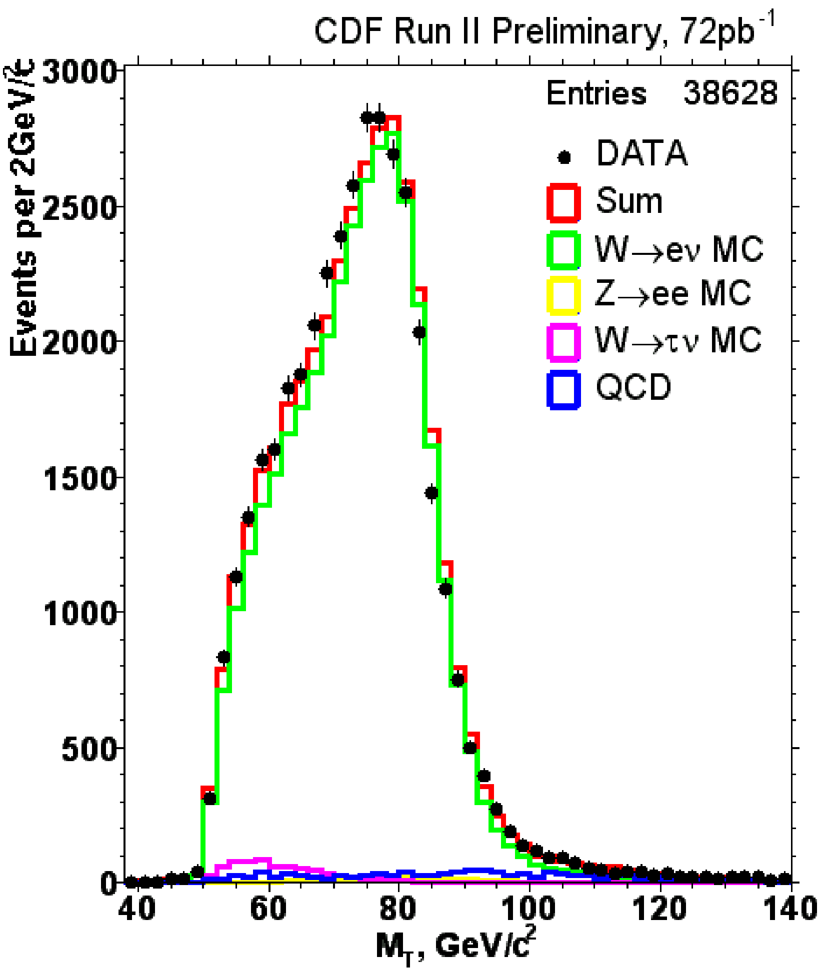
$\sigma * B(W \to e\nu)$

Event selection

One isolated high p_T central e

$\not{E}_T > 25$ GeV

Number of Candidates:
38628 in 72 pb^{-1}
Background (~6.4%):
QCD: 1344 ±82 ±672
$Z \to ee$: 344 ± 17
$W \to \tau\nu$: 768 ± 22



$\sigma_Z * B(W \to e\nu) = 2.64 \pm 0.01_{stat} \pm 0.09_{syst} \pm 0.15_{lum}$ nb

NNLO @ $\sqrt{s}$=1.96 TeV: 2.69 ± 0.10 nb

$\sigma_W * B(W \rightarrow \mu\nu)$

Event selection

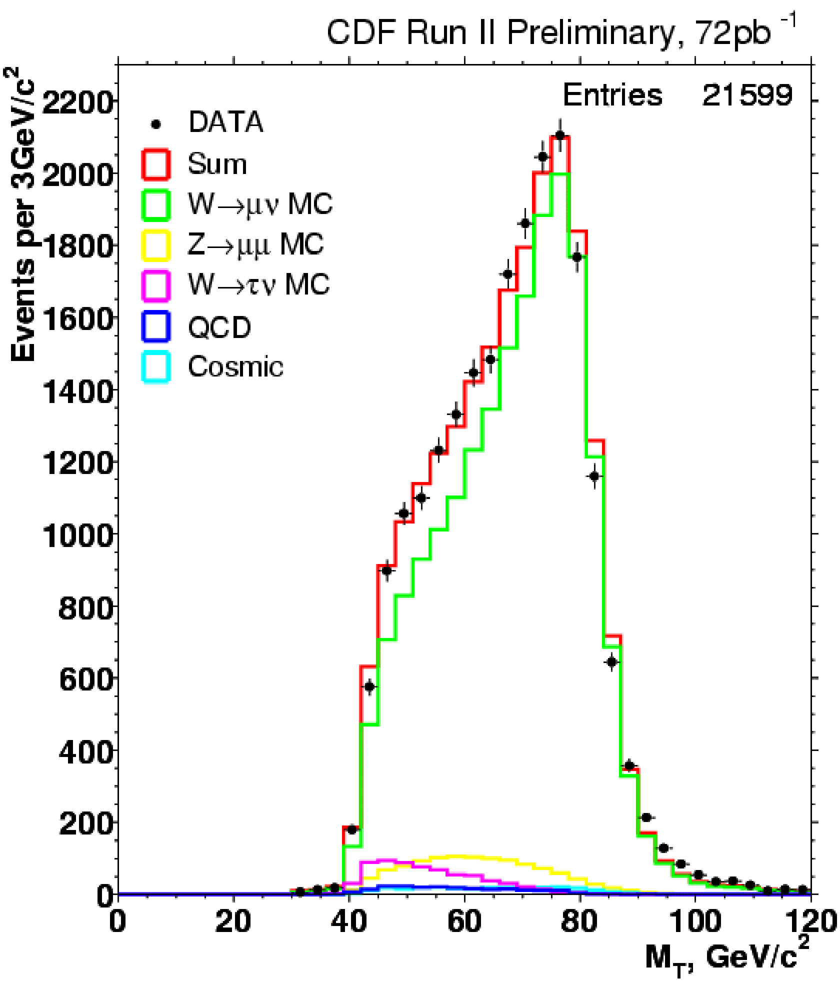
One isolated high p_T central μ

$P_T > 20$ GeV

Veto Z and Cosmics

Number of Candidates:
- 21599 in 72 pb^{-1}

Background (11%) :
- QCD: 222 ± 58
- cosmics: 276 ± 195
- $Z \rightarrow \mu\mu$: 1147 ± 44
- $W \rightarrow \tau\nu$: 691 ± 31



$\sigma_W * B(W \rightarrow \mu\nu) = 2.64 \pm 0.02_{stat} \pm 0.12_{syst} \pm 0.16_{lum}$ nb

$\sigma_W * B(W \to \tau\nu)$

Event selection

One isolated (cal+track) high E_T central τ

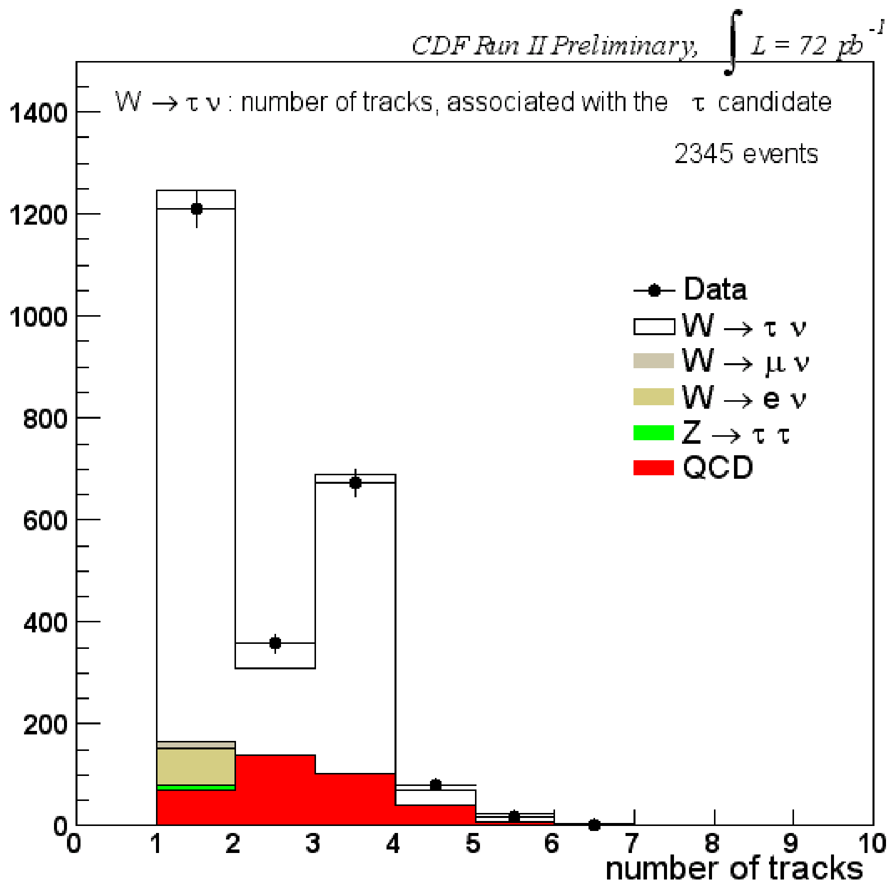
$\not{E}_T > 25$ GeV

e removal

Candidates: 2345 in 72 pb^{-1}

Backgrounds (~ 26 %):

- QCD: 363 ± 52
- $W \to e\nu$: 103 ± 11
- $W \to \mu\nu$: 91 ± 27
- Cosmics: 35 ± 13
- $Z \to \tau\tau$: 20 ± 2



$\sigma_W * B(W \to \tau\nu) = 2.62 \pm 0.07_{stat} \pm 0.21_{syst} \pm 0.16_{lum}$ nb

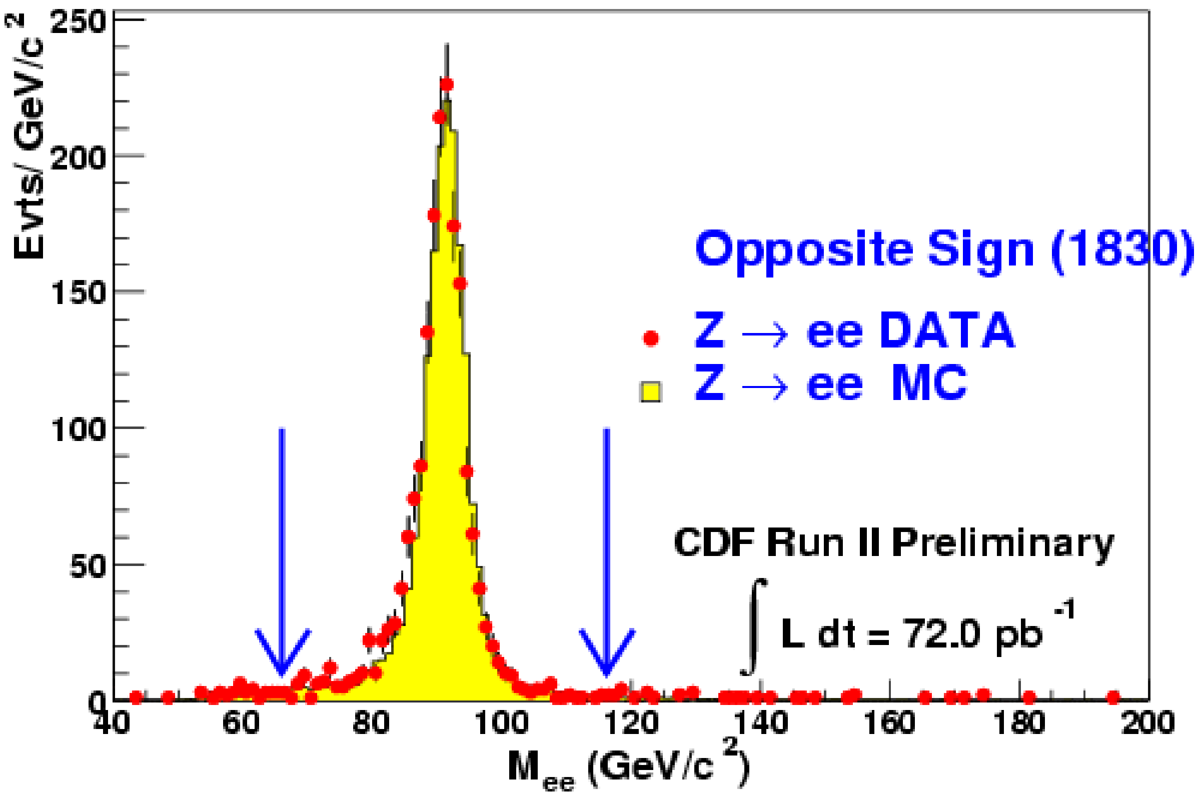
σ_Z*B(Z→ee)

Luminosity: 72 pb^{-1}

Observed Events: 1830 Events

Background (~0.5%): $8.7 \pm 4.7_{stat} \pm 2.4_{syst}$

NNLO Prediction: 252 ± 9 pb



σ_Z*B(Z→ee) = $267.0 \pm 6.3_{stat} \pm 15.2_{syst} \pm 16_{lum}$ pb

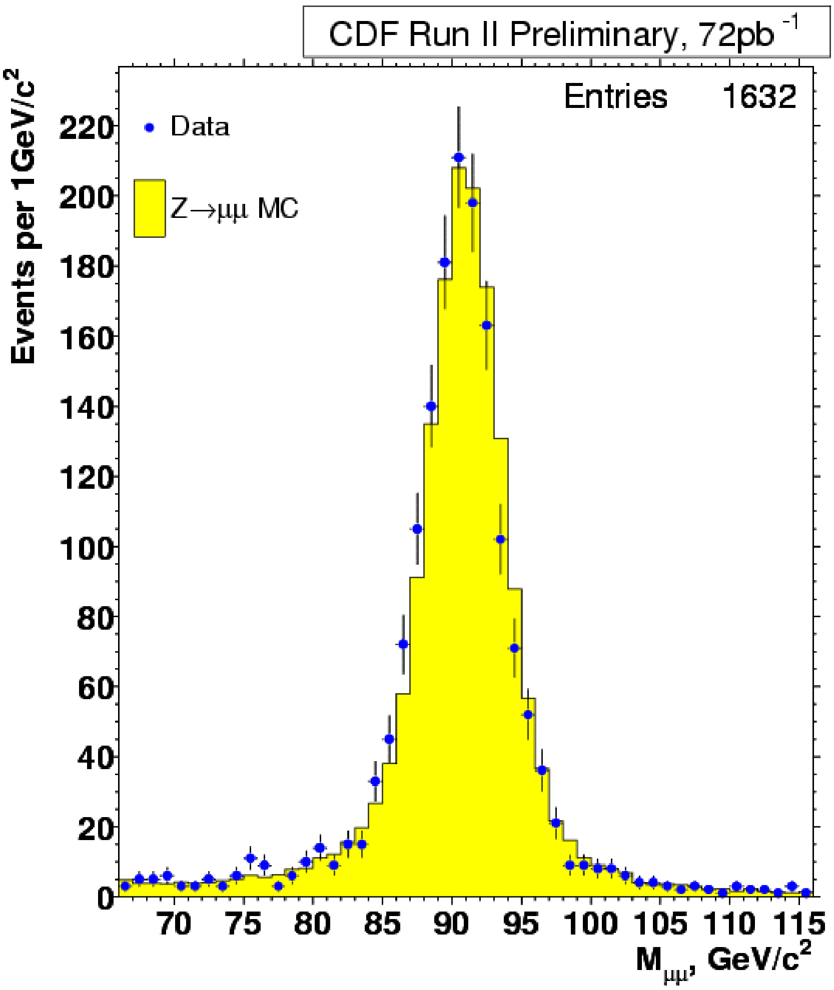
σ_Z*B($Z \rightarrow \mu\mu$)

Luminosity: 72 pb^{-1}

Observed Events: 1632 Events

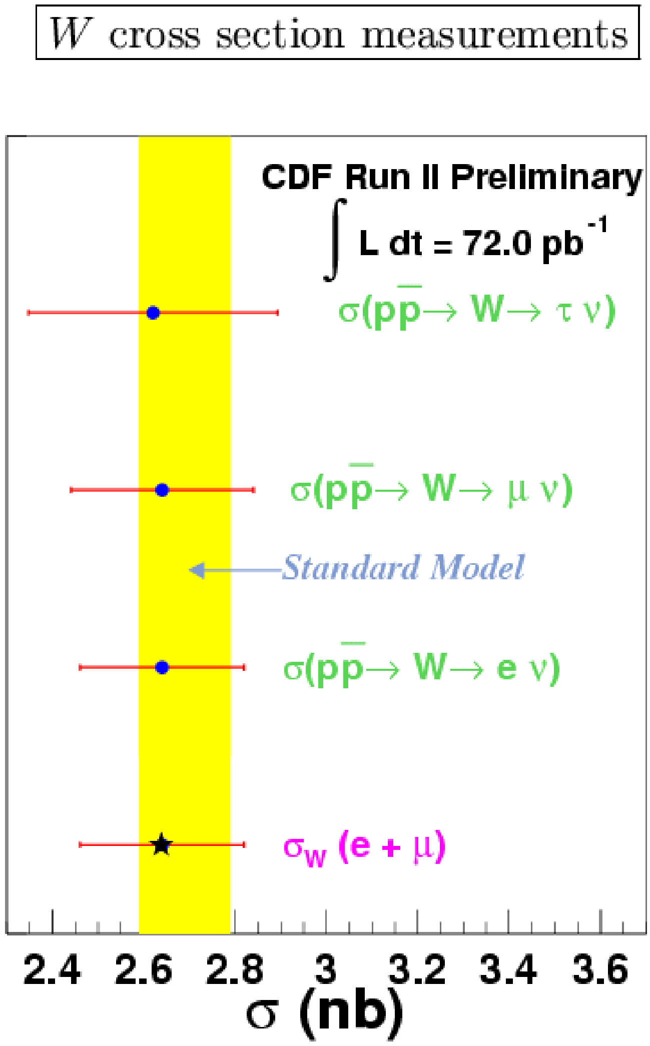
Background (~0.8%): 14 ± 14

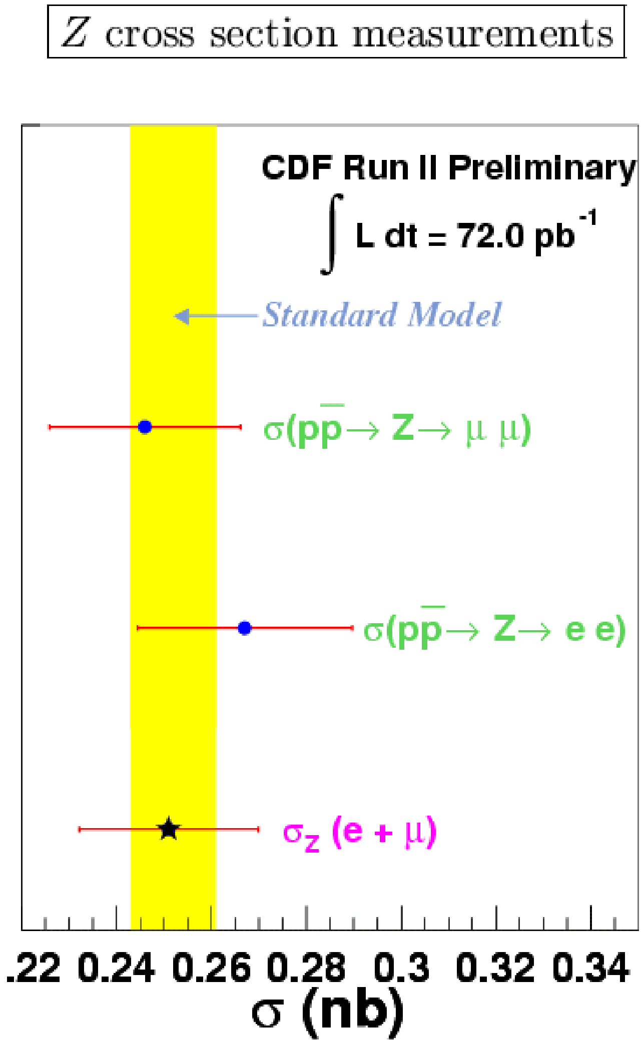
NNLO Prediction: 252 ± 9 pb



σ_Z*B($Z \rightarrow \mu\mu$) = 246 ± 6_{stat} ± 12_{syst} ± 15_{lum} pb

Summary of W and Z Cross Sections





Combined W and Z Cross Sections

$\sigma_W = 2.640 \pm 0.012_{stat} \pm 0.093_{syst} \pm 0.158_{lum}$ pb

$\sigma_Z = 251.5 \pm 4.3_{stat} \pm 10.6_{syst} \pm 15.1_{lum}$ pb

SM Consistency Checks

Measure — Theoretical prediction — PDG SM — PDG combined Exp

$$R = \frac{\sigma(pp \to W)\, \Gamma(W \to e\nu)\, \Gamma(Z)}{\sigma(pp \to Z)\, \Gamma(W)\, \Gamma(Z \to ee)}$$

Extract

R_e	$9.88 \pm 0.24_{stat} \pm 0.47_{sys}$
R_μ	$10.69 \pm 0.27_{stat} \pm 0.33_{sys}$
$R_{combined}$	$10.54 \pm 0.18_{stat} \pm 0.33_{sys}$
$\Gamma(W)e$ [GeV]	$2.29 \pm 0.06_{stat} \pm 0.10_{sys}$
$\Gamma(W)\mu$ [GeV]	$2.11 \pm 0.05_{stat} \pm 0.07_{sys} \pm 0.02_{ext}$
$\Gamma(W)_{comb.}$ [GeV]	2.146 ± 0.078

R = 10.67 ±0.15 NNLO(1.96 TeV)	[Nucl. Phys. B359,343 (1991)] [Phys.Rev. Lett. 88,201801 (2002)]
$\Gamma(W)$: 2.118 ± 0.042 GeV	[Phys. Rev. D66, 2002 (PDG fit)]
$\Gamma(W)$: 2.0921 ± 0.0025 GeV	[Phys. Rev. D49, 2002]

$$\frac{BR(W \to \tau\nu)}{BR(W \to e\nu)} = 0.99 \pm 0.04_{stat} \pm 0.07_{sys}$$

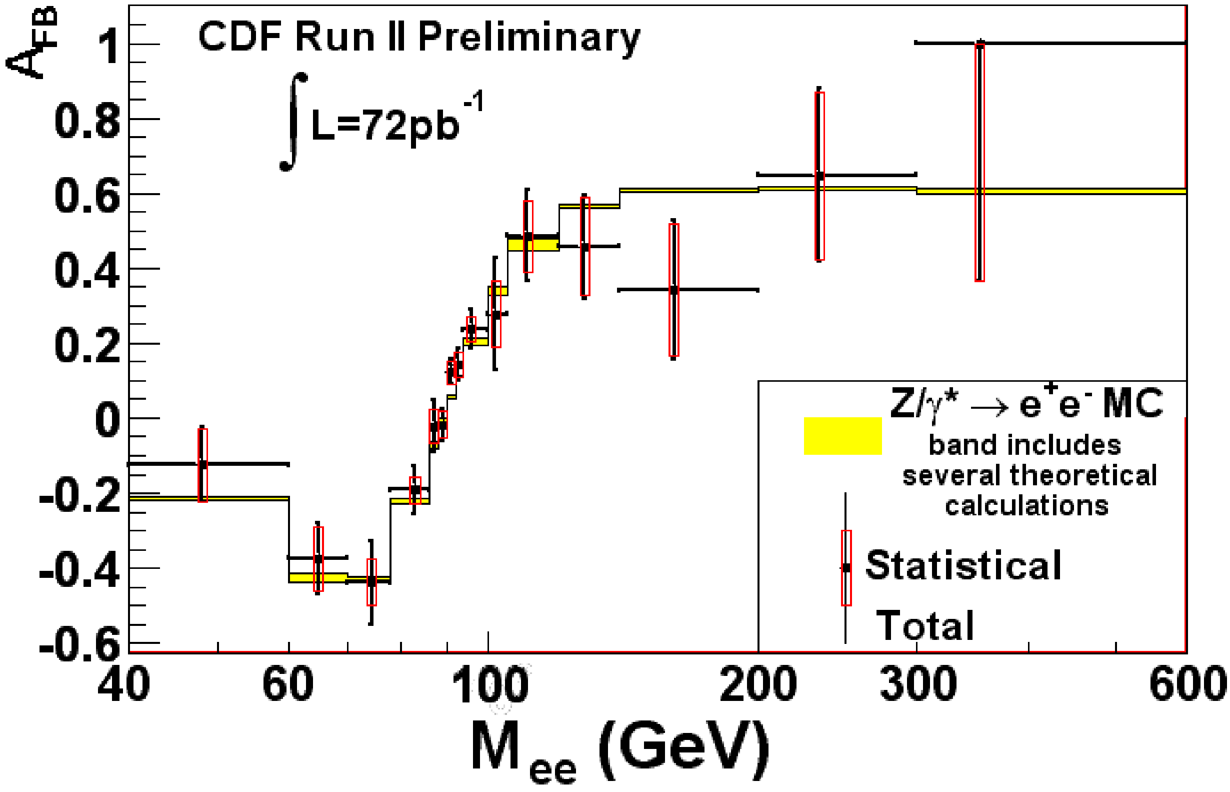
$$\frac{g_\tau}{g_e} = 0.99 \pm 0.02_{stat} \pm 0.04_{sys}$$

Forward Backward Asymmetry (A_{FB})

$$\frac{d\sigma(q\bar{q} \to Z/\gamma \to e^+e^-)}{d\cos\theta} = A(1+\cos^2\theta) + B\cos\theta$$

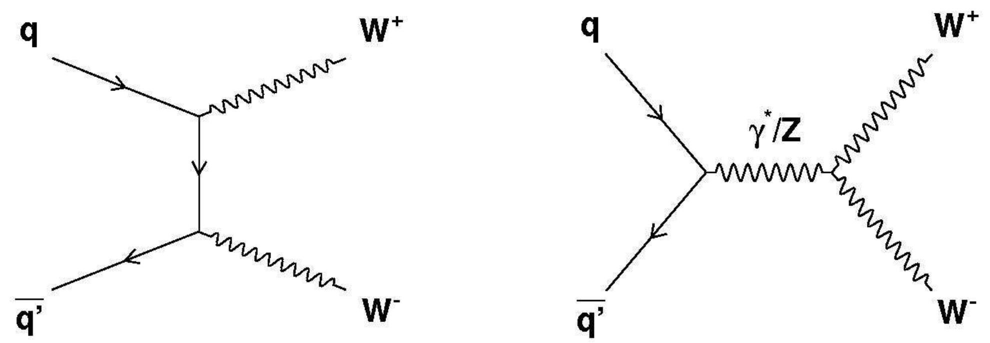
$$A_{FB} = \frac{N_F - N_B}{N_F + N_B} = \frac{\sigma(\cos\theta>0)-\sigma(\cos\theta<0)}{\sigma(\cos\theta>0)+\sigma(\cos\theta<0)} = \frac{3B}{8A}$$

A, B depend on $I_,\ Q_{q,}(M_{ll})^2$

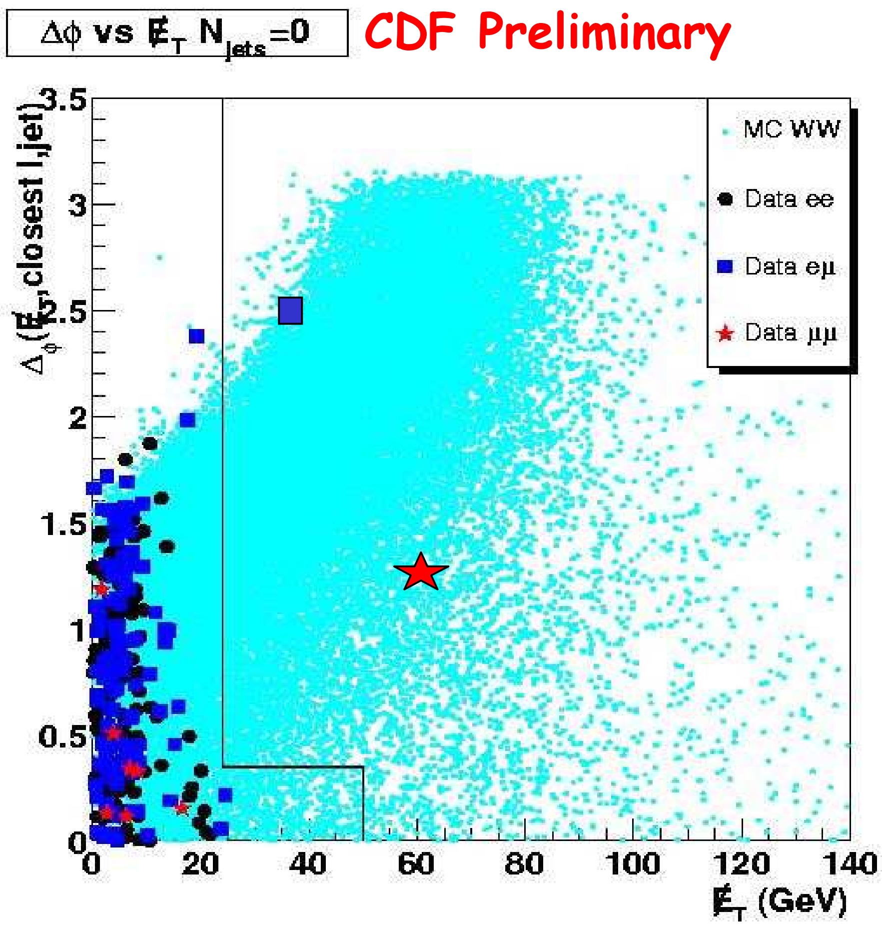


- A_{FB} is a direct probe of the relative strengths of the vector and axial-vector couplings.
- A_{FB} modified by neutral gauge bosons beyond the SM.
- Extract $\sin^2\theta^{eff}$ from A_{FB}.

WW pair production



CDF Preliminary



2 candidate events in 72 pb^{-1}

SM expectation:

2.74 ± 0.59

Background:

1.52 ± 0.64

Extrapolation of Run I results

Theory: 1.8 TeV → ~9.5 pb with 10% uncertainty

Theory: 1.96 TeV → 13.25 ± 0.25 pb (hep-ph/9905386)

Run I CDF experiment → 10.2 +6.3-5.1 (stat) ± 1.6(sys) pb

Run II Extrapolation: 10.2 * (13.25/9.5) = 14.2 pb

Top Quark Physics

The Discovery of the top quark in 1995 was no big surprise. What was surprising is that its mass is almost 40 times that of the b quark, and tantalizingly close to the scale of EWSB.

The Fermilab Tevatron has been the only place, and will be until the LHC turns on in ~2008, to study the top quark.

Everything we know about top is based on about 100 events from the Tevatron Run 1 by the D0 and CDF collaborations.

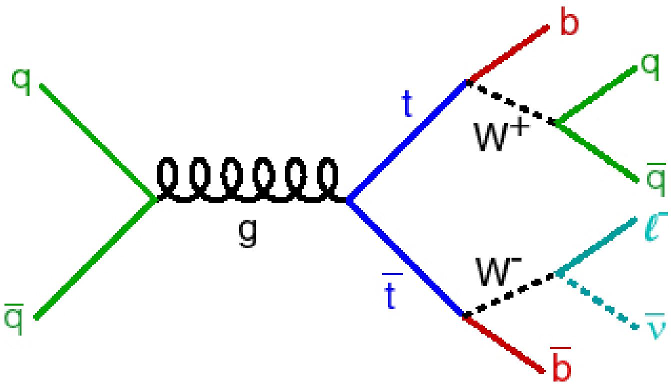
With 30 times more top events, as expected in Run 2a, we hope to try and answer such questions as:

- ➔Why is top so heavy ?
- ➔Is it or the third generation special ?
- ➔Is top involved with EWSB ?
- ➔Is it connected to new physics ?

Production and Decay of the Top Quark

At the Tevatron, top quarks are primarily produced in pairs.

τ_{top} ~ 4×10^{-25} s
Λ^{-1} ~ 10^{-23} s
Top decays as free quark!
BR(t→Wb) @ 100 %

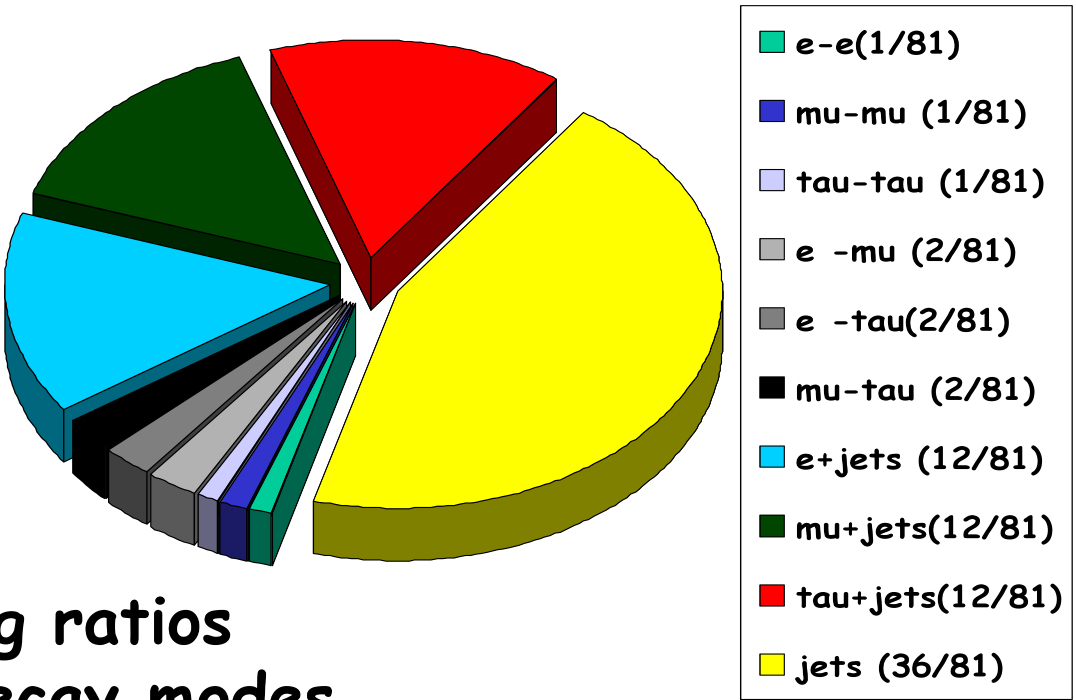


3 classes of signal

Dilepton: 2 high-P_T leptons, 2 bjets, large Missing E_T: BR 5%

Lepton + jets: 1 high-P_T lepton, 4 jets (2 b's), large $\not{E}_T$: BR 30%

All-hadronic: 6 jets : BR 44%

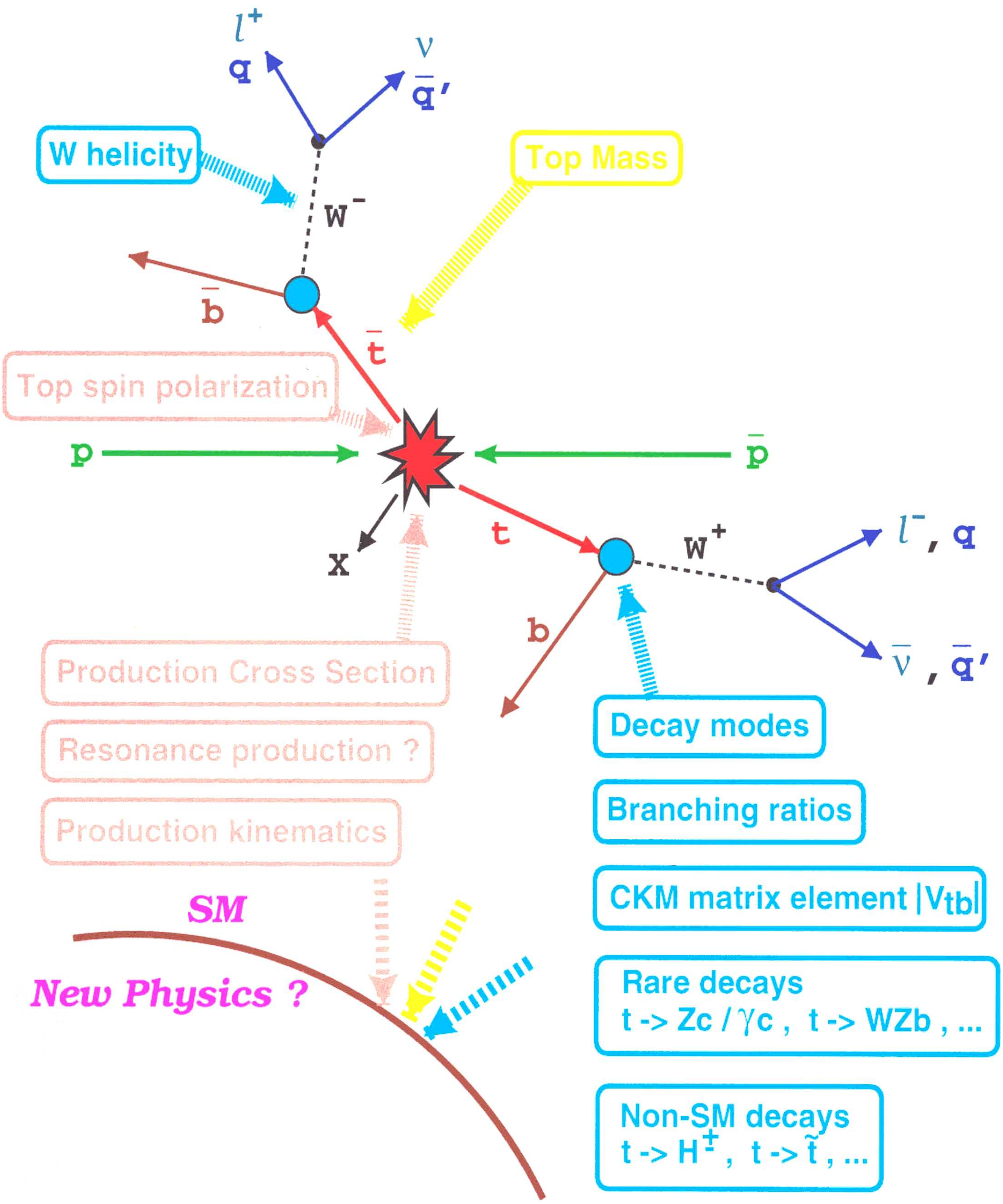


Branching ratios for tt decay modes

Top production numbers

	Run 1	Run 2a
CM Energy (TeV)	1.8	1.96
L(cm^{-2} s^{-1})	2×10^{31}	2×10^{32}
L(fb^{-1})	0.11	2.0
σ(tt) (pb)	5.0	7.0
σ(single top) (pb)	2.5	3.4
N(tt) produced	500	14000
N(single t) produced	250	7000
N(tt–>dilepton)	4	150
N(tt–>l+3j) (1tag)	25	1400
N(tt–>l+4j) (2tags)	5	600

Top Properties



Top cross section

Measurement of the cross section is primarily a "counting experiment"

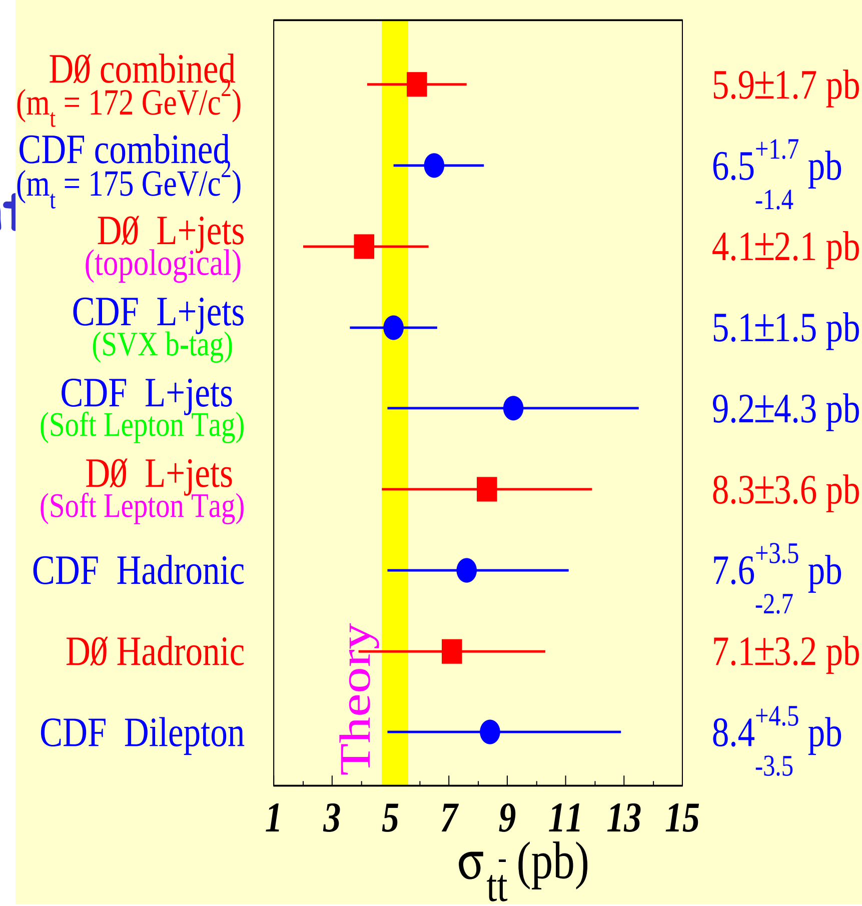
$$\sigma(t\bar{t}) = \frac{N_{obs} - N_{bkg}}{A \cdot \int L}$$

$$\sigma_{t\bar{t}}(\sqrt{s} = 1.96\,\text{TeV}) \approx 1.30 \times \sigma_{t\bar{t}}(\sqrt{s} = 1.8\,\text{TeV})$$

Measure in different decay channels and using different Techniques.

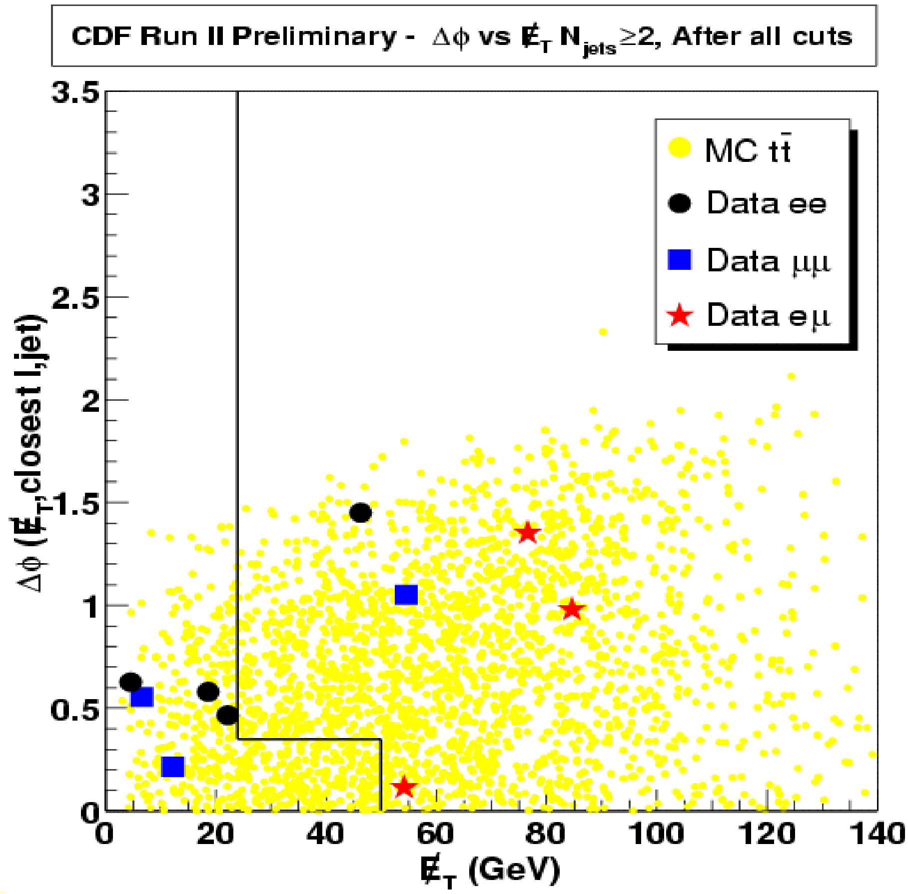
b-tagging, kinematic Fitting, Neural Nets

Run 1 cross section results ~100 pb^{-1}



σ_{tt} dilepton cross section

- Event selection
  - 2 High P_T (P_T>20 GeV) oppositely charged leptons (e,μ).
  - Both isolated: I_{CAL}< 0.1
  - Veto Z's, cosmics, and conversions
  - Neutrinos: large missing E_T > 25 GeV
  - at least 2 jets with E_T > 10 GeV
  - Total transverse energy of the event > 200 GeV
- BR~5%, detection eff ~ 11%, expect S/B~9, S~2.5
- 5 candidate events in 72 pb^{-1}
- Backgrounds from Drell Yan, $Z^0 \to \tau\tau$, WW : 0.30 ± 0.12

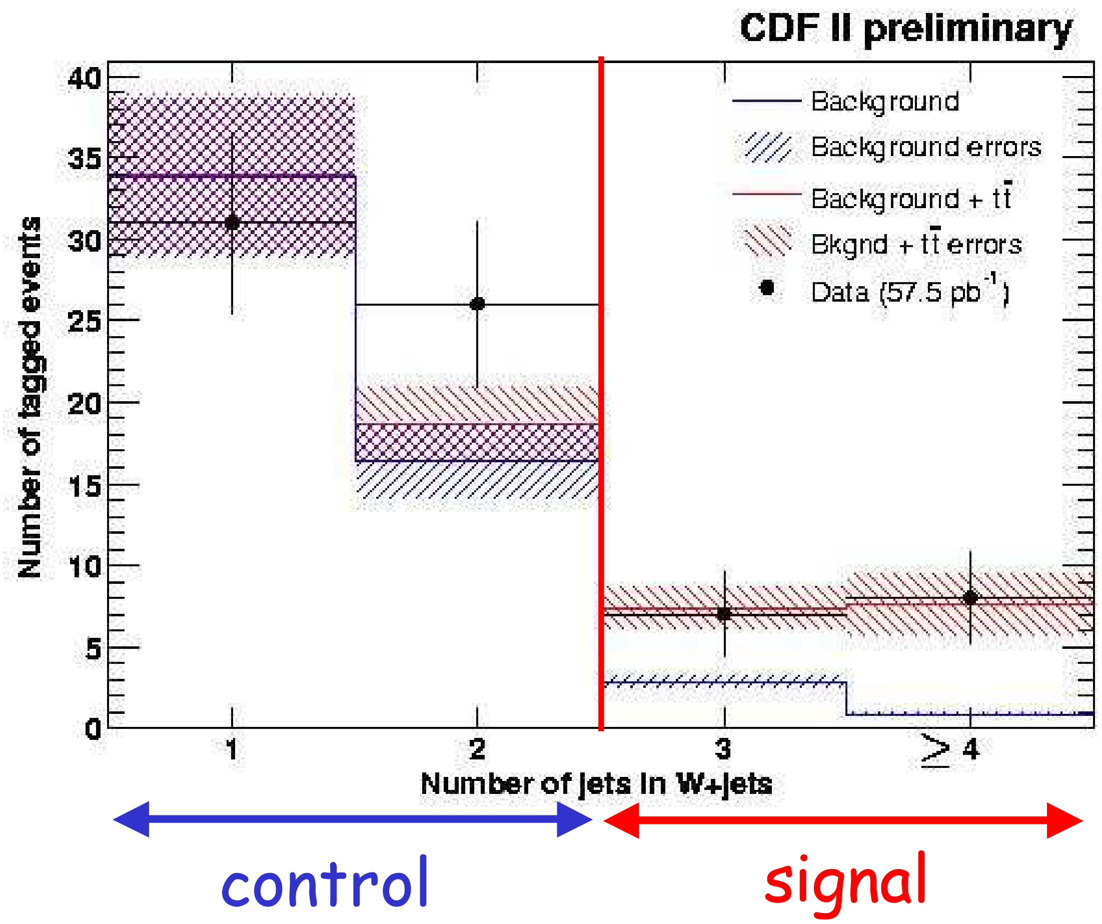


$$\sigma_{tt} = 13.2 \pm 5.9_{stat} \pm 1.5_{syst}\ pb$$

NLO for M_{top} = 175 GeV: $6.70^{+0.71}_{-0.88}$ pb

σ_{tt} : lepton + jets

- Event selection
  - 1 High momentum, central, and isolated lepton
    - P_T>20 GeV/c, e or μ.
  - Veto Z's, cosmics, and conversions
  - Neutrinos: large missing E_T > 20 GeV
  - 3 or more jets with E_T > 15 GeV
  - at least 1 jet with secondary vertex tag (SVX)
- 15 observed events in 57.5 pb^{-1}
- Backgrounds from Wbb,Wcc,mistags,Wc, non-W: 3.8 ± 0.5

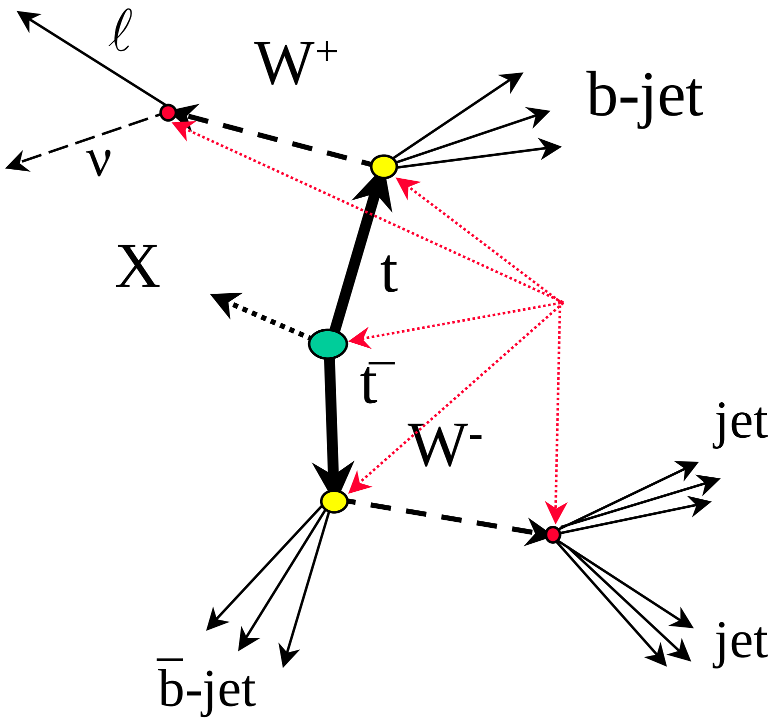


$$\sigma_{tt} = 5.3 \pm 1.9_{stat} \pm 0.8_{syst}\ \text{pb}$$

NLO for M_{top} = 175 GeV: $6.70^{+0.71}_{-0.88}$ pb

Top mass: lepton + jets

Select lepton + 4 jet events, similar to the σ(tt) measurement, except no requirement on silicon.



METHOD

Use 2C constrained fitting technique with constraints

$M_{l\nu}=M_W$, $M_{jj}=M_W$,$M_{t1}=M_{t2}$

24 combinations:

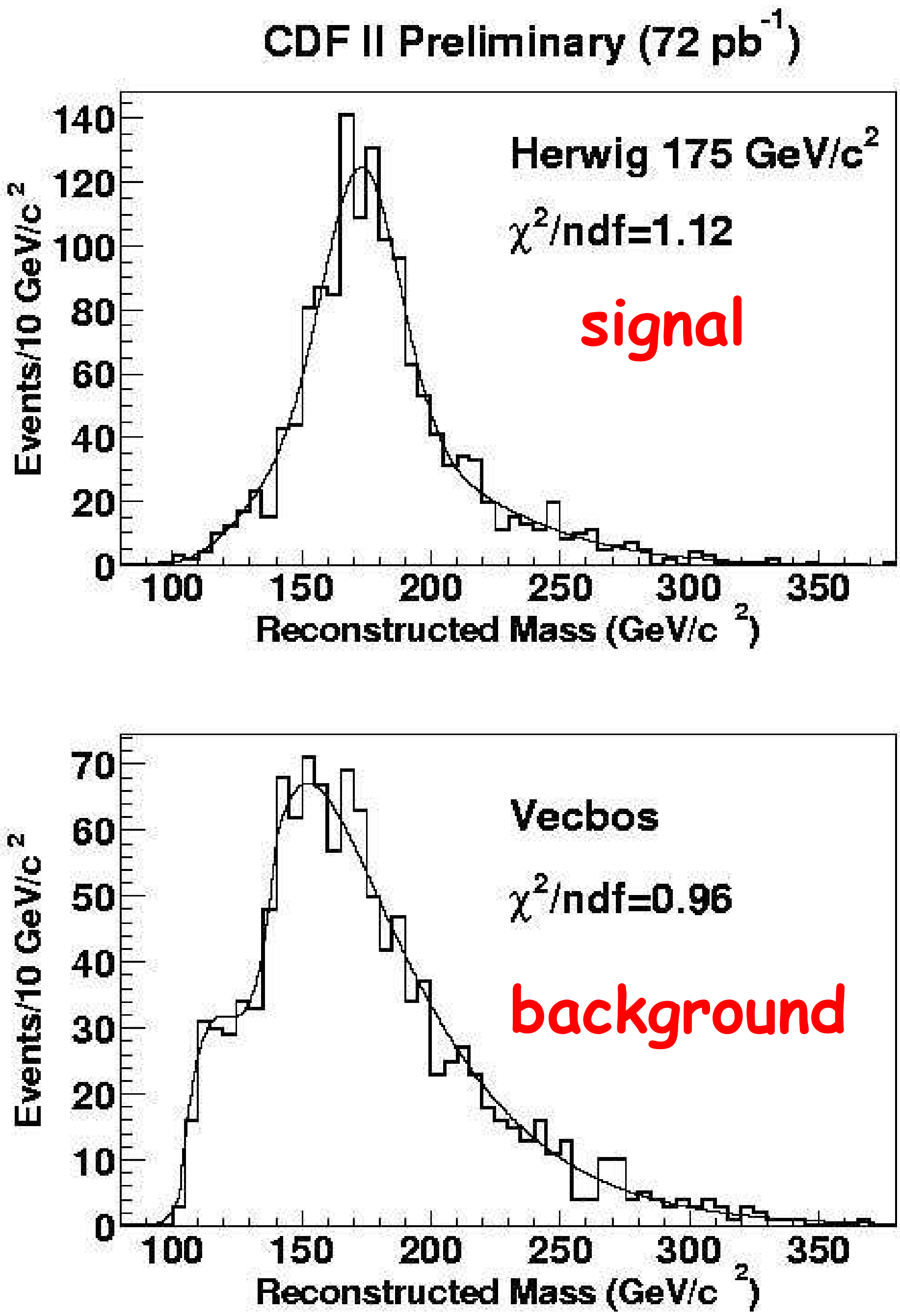
12 correspond to the jet parton match

every combination has 2 solutions for neutrino P_Z

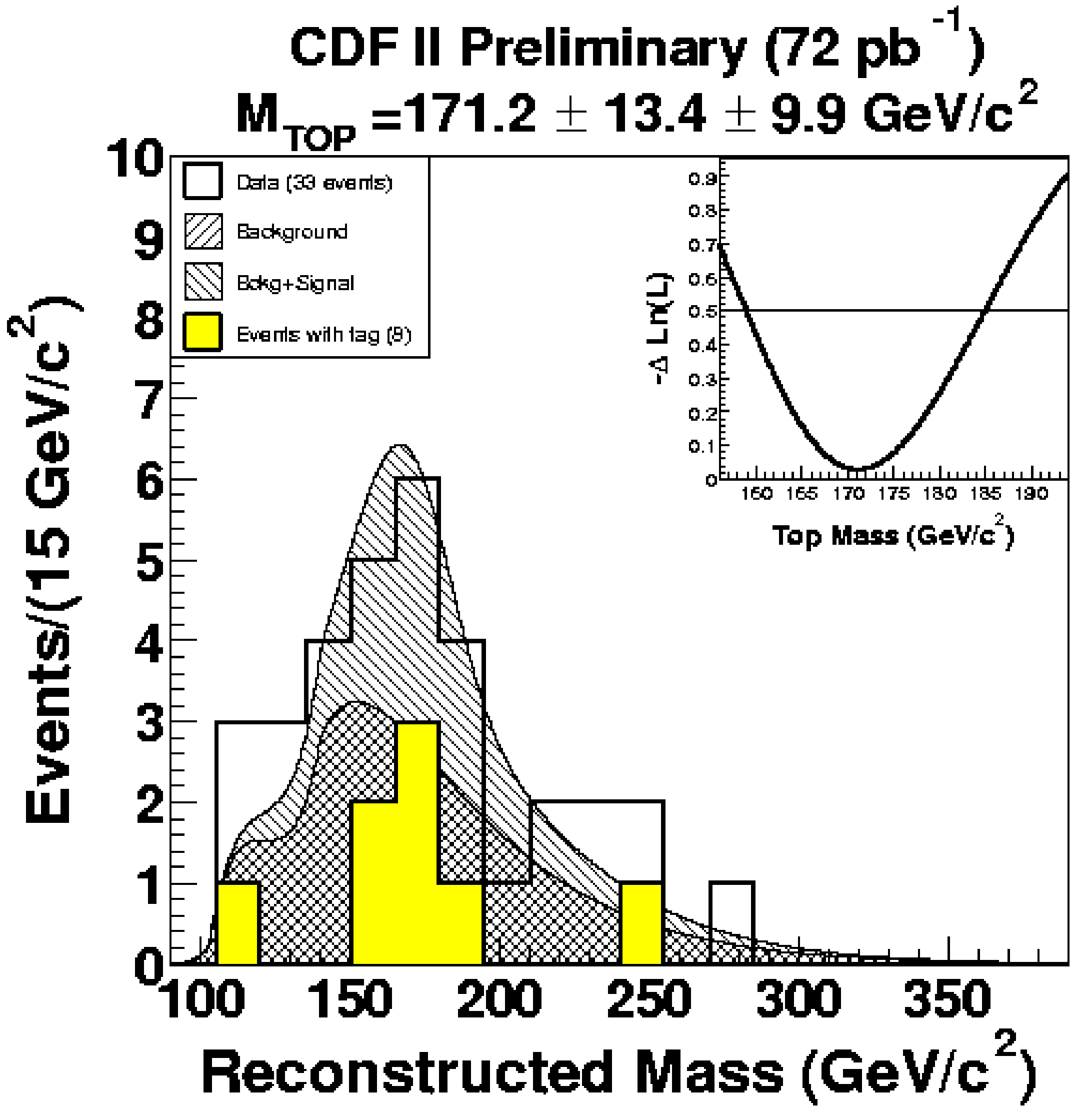
Choose combination with lowest χ^2.

Top mass

Reconstructed top masses from data are compared to parameterized templates of top and background Monte Carlo.



Top mass



CDF Run 1 combined 176.1 ± 6.5 GeV/c^2

Use a continuous likelihood method to extract top mass and statistical uncertainty

M_{top} is the minimum of the log-likelihood distribution

σ_{top} corresponds to a change of 0.5 units in the log-likelihood

Summary

- Run 2a is well underway and we are in the process of reestablishing some basic physics measurements and getting a better understanding of the CDF detector
  - W/Z Cross Sections and Ratios
  - tt Cross Section
  - Top mass
- Some of the more complicated analyses will follow
  - W Mass
- With larger samples (later this year) we will be able to extend our Run I searches for extensions to the standard model
  - Diboson couplings
  - Top Properties
- By summer we hope to have ~200 pb^{-1}.
- Goal for Run 2a is still 2000 pb^{-1}